Charles

FROM RAVI PRASAD

High Bulk Density of Tobacco

Generally, loading a bed of tobacco into an impregnation vessel via gravity results in a more compacted tobacco at the bottom of the bed compared to the top of the bed. This variation in the bulk density of the tobacco needs to be taken into account during the impregnation cycle so that the top and the bottom layers of the tobacco bed are equally impregnated.

During the impregnation process, the bed of tobacco filled into the impregnator via gravity settles to some degree depending on its moisture content and the height and diameter of the bed. This results in the formation of "void" space at the top of the tobacco bed. The CO_2 gas present in this void space, upon depressurization, can result in excessive cooling and, therefore, non-uniformity of impregnation.

The NET-SCI process uses high bulk density tobacco. The bulk density of tobacco is higher than what can be obtained by the gravity filling of the impregnation chamber. The volume of the impregnator and the batch size is kept relatively small. As a result, the high bulk density obtained (via mechanical compression for example) results in a very uniform packing density of the tobacco bed. During impregnation, due to the precompressed nature of the bed of tobacco, very little to zero additional settling takes place. Hence, no void space (or very little void space) is formed due to the settling of the tobacco bed during the impregnation cycle. Upon depressurization, more uniform impregnation is obtained.

NET process uses a two step pressurization process. The first step is to pressurize with CO_2 from 0 to 250 psig (compression ratio 18:1). Due to the high compression ratio of the first pressurization step, a significant amount of heat of compression occurs in the impregnator. This heat of compression results in CO_2 (g) "hot spots" that tend to localize (due to the buoyancy effect) to the top section of the impregnator. An important task of the NET-SCI process is to remove the hot spots and to precool the tobacco to a low temperature in an efficient manner to minimize both the time taken and the amount of CO_2 usage.

The high bulk density used in the NET-SCI process provides a very uniform flow of CO_2 gas at 250 psig from the bottom to the top of tobacco bed to flush out the "hot spots" via displacement. The amount of CO_2 and the time needed for the removal of hot spots and the subsequent cooling of tobacco are both minimized via the uniformity of gas flow.

After the "hot spots" are removed, the precooling of tobacco can be continued in the same fashion. However, due to the high packing density, the precooling can be carried out just as efficiently in the horizontal direction as it is in the vertical direction. Uniform "precool" tobacco temperature is obtained due to the homogeneity of the tobacco bed (i.e., uniformly high packing density without void spaces) and the uniformity of CO_2 flow through the bed of tobacco. This leads to several advantages as explained later.

2026345305

The second pressurization step is to increase the CO_2 pressure from 250 psig to 800 psig. The amount of heat generated due to compression is relatively small due to the low compression ratio of about 3:1.

Due to the high compaction of tobacco used in NET-SCI process, the ratio of impregnator volume to the amount of tobacco is substantially reduced (by 50% in going from 7 lbs/ft^3 to 14 lbs/ft^3 tobacco packing density). Obviously, the amount of CO_2 used and the amount of heat of compression generated are also significantly reduced based on a unit of tobacco weight processed. This is an additional advantage of the high build density of tobacco as the cost of operation (including emissions of CO_2 and the cost of energy to recompress the CO_2.) is reduced per pound of tobacco. As there is more tobacco present in a unit volume of the impregnator, there is more condensed CO_2 present to neutralize the effect of the heat of compression. Therefore, the problem of non-uniformity of impregnation is avoided by using high bulk density of packed tobacco in a short cycle process of tobacco impregnation.

In normal processing, the cycle time is at least partly limited by how fast the CO_2 gas can flow through a bed of tobacco. Generally, the CO_2 gas velocity is limited to the entrainment velocity of tobacco in order to avoid tobacco degradation/carryover. In short cycle impregnation, using high bulk density tobacco, the flow of CO_2 can be significantly faster. This is because there are no void spaces, and the bed of tobacco is totally supported on all sides. The higher CO_2 flow allows the cycle time to be shorter, thus reducing the batch size even further for a given production throughput. The higher gas velocity may be used during all the steps of the impregnation process (pressure up, flow through cooling, and vent) without the movement of the tobacco bed.

<u>Uniform Condensation/No Manifestation of Heat of Compression Buildup</u>

As the pressure builds up during the second stage of pressurization, CO_2 gas comes in contact with tobacco at a temperature lower than its saturation temperature. As a result, a controlled amount of CO_2 condenses uniformly on tobacco, and the tobacco temperature increases to the CO_2 saturation temperature. Throughout the process, the CO_2 gas always remains at the saturation conditions as the liquid CO_2 is always present on tobacco. The small amount of heat-of-compression does not result in any "hot spots" as the excess heat is immediately used up in reducing the condensation of liquid onto the tobacco (or in evaporating a fractional amount of CO_2 liquid that had already condensed). This reduction in liquid CO_2 on tobacco is also very uniform as no "hot spots" or void spaces exist. The amount of liquid CO_2 formation is a function of heat balance (thermodynamic properties!) between the "beginning" and the "ending" conditions of CO_2 and tobacco properties. It is unaffected by the physical location of the inlet and outlet nozzles, top vs bottom, or the direction of CO_2 flow, or the packing density of tobacco. Therefore, the uniformity of CO_2 liquid condensation on tobacco is assured. This is an important consideration in achieving the uniform impregnation of tobacco.

2026345306

During vent, the majority of cooling is provided by the evaporation of liquid CO_2 already condensed uniformly on tobacco. Due to a lower CO_2 gas to tobacco ratio, the contribution of gaseous expansion in cooling tobacco is small. Moreover, the absence of any void spaces makes the total cooling process very uniform. A uniform post vent temperature results giving tobacco with a uniform level of impregnation and uniform stability. The uniformity of impregnation is not affected by the gas flow direction during vent (Vertical, Horizontal, Radial, etc.).

The higher bulk density requires smaller impregnator size, which reduces the cost of capital equipment. Also, as smaller batches are processed over shorter time intervals, the bulking storage requirements for the impregnation/expansion process are significantly reduced, i.e., less capital cost.

SCI

The small amount of tobacco processed over a very short cycle time results in an operation approaching a continuous process. The hold-up time of impregnated tobacco being fed to the expansion tower is significantly reduced (1 hour hold-up for batch impregnation vs 2 to 5 minute hold-up for short cycle process). This allows the processing of tobacco with a higher post vent temperature/reduced stability. The advantage of this feature is that it allows the cycle time to be shortened even further as the hold time for tobacco under CO_2 pressure for impregnation does not have to be very long. Also, a second advantage is that cold/dry/inert gas atmosphere needed for the one hour storage stability requirement can be made less stringent and less costly for short cycle operation, i.e., insulation and a sweep of inert gas may be all that is required, saving the cost of refrigeration heat exchangers.

As we approach continuous operation, the uniformity of expanded product is improved over the batch process using large batches of tobacco with long hold-up times.

NET

This process can impregnate at any bulk density as the mechanism of impregnation/cooling is based on a certain controlled amount of CO_2 liquid condensing on the tobacco. The process is not dependent on the amount of CO_2 gas to tobacco ratio. The range of bulk densities that can be impregnated is as low as 5-7 lbs/ft^3 used in ordinary tobacco handling to as high as 12-14 lbs/ft^3 obtained by mechanical compression or other processing aids not commonly used in tobacco processing. There are important processing and cost advantages in using high bulk density tobacco in a NET process including: a)reduced CO_2 usage, b)reduced capital cost, c)reduced cost of CO_2 recovery (both capital and energy costs), d)more uniform impregnation of tobacco, and e)reduced environmental concerns, i.e., CO_2 emissions, etc.

2026345307